VOLUME 77 SEPARATE No. 101

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

NOVEMBER, 1951

APPLICATION OF HIGHWAY CAPACITY RESEARCH

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HIGHWAY DIVISION

Headquarters of the Society
33 W. 39th St.
New York 18, N.Y.

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Published at Prince and Lemon Streets, Lancaster, Pa., by the American Society of Civil Engineers. Editorial and General Offices at 33 West Thirty-ninth Street, New York 18, N. Y.

Proceedings—Vol. 77 November, 1951 Separate No. 101

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

PAPERS

APPLICATION OF HIGHWAY CAPACITY RESEARCH

BY J. P. BUCKLEY,[1] M. ASCE

SYNOPSIS

Practical application of the principles of highway capacity research are outlined in this paper. The development and use of comprehensive capacity charts are illustrated for the cases of two-lane rural roads, two-way city streets, and one-way city streets.

INTRODUCTION

The principles of highway capacity research as well as the practical applications of these principles are outlined in the paper by O. K. Normann. The study referred to in that paper[2] is recognized as one of the most thorough in highway research history and one of the most important advancements in highway engineering in many years.

Capacity, the number of vehicles a highway, road, or street can accommodate safely and efficiently, is one of the fundamental problems in motor transportation. The objective of highway engineers in this field is to provide sufficient capacity on highways and streets to safely and efficiently carry the traffic volumes at the minimum cost. Inaccurate estimations of required capacity can be costly, since the design and construction of facilities with more than required capacity is obviously a waste of public funds. However, under-design, or failure to provide adequate capacity, is equally wasteful. Lack of capacity means congestion, costly delays, and accidents, and often the cost of correction is far more than the cost of proper initial design and construction.

Although highway capacity has been extensively studied for many years, the work of the committee on Highway Capacity of the Highway Research Board covers the subject more extensively than any previous investigation and

NOTE.—Written comments are invited for publication; the last discussion should be submitted by **May 1, 1952.**

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[2] "Principles of Highway Capacity Research," by O. K. Normann, *Proceedings-Separate No. 105*, ASCE, November, 1951.

gives the basic factors necessary to insure greater accuracy in capacity determinations and design.

Planning of Surveys

Design engineers and traffic engineers are continuously faced with the problem of capacity determinations on specific sections of highways and streets. However, the problem is more complex in connection with state-wide highway planning studies.

The principal objectives of these studies are to determine the physical deficiencies and needs of all highways, roads, and streets in the state and to prepare a long-range plan to meet these needs on an efficient and economical basis.

In a highly urbanized state, such as Ohio, with many large cities and extensive mileage of roads and streets carrying high traffic volumes, the problem of capacity has unusual importance. Not only must the practical capacity of the existing roads and streets be determined, but in addition it is necessary to know the type of design required to provide adequate capacity at a minimum cost on new facilities. The extensive mileage of roads involved in this determination requires that the field studies be made by several hundred state, county, and city engineers. Since these engineers take on this work in addition to their regular activities and since there is a time factor, it is highly important that the task be simplified by every possible means without sacrificing accuracy. Further, since one of the requirements of the survey is to determine the comparative needs of the state highway, county, and city systems, the work must be done on a uniform basis with standards of appraisal. Finally, in view of the large amount of detail involved and the importance of producing a sound and accurate program, the central supervisory engineering staff of the study must have a method of checking the projects submitted by state and local engineers to insure their accuracy. So, far as capacity is concerned, the work of the Committee on Highway Capacity has provided the tools for meeting these conditions.

However, Mr. Normann has indicated the very large number of variables involved in the determination of capacity, lane width, sight distance, terrain, operating speed, and many others. The comprehensive report of the Committee shows the importance of sound engineering judgment in applying the data. The problem, then, is to determine a method of applying the basic factors on a mass production basis within reasonable limits of accuracy.

Highway Capacity Charts

As part of the organization of the Ohio Highway Study Committee, special engineering advisory committees, composed of the state's most able highway and traffic engineers, were established. Following several months of study of the report of the Highway Capacity Committee, a series of three basic circular charts were prepared for use in determining the capacity of: (*a*) two-lane rural roads; (*b*) two-way city streets; and (*c*) one-way city streets. These three charts actually are the final product of a long series of charts combined for more efficient handling. The circular scheme lends itself to a tabular arrangement of a number of variables in a limited space.

The normal method of applying the capacity factors for a specific problem would be to consider successively each of the factors that affect capacity and go through the mathematical steps of applying these factors to arrive at the final answer. In preparation of the charts the staff engineer has gone through this process for several hundred possible sets of conditions. To simplify the work, only the basic factors that have a material effect on capacity were considered in this process. Field checks in several parts of the country have indicated that the limits of accuracy are reasonable.

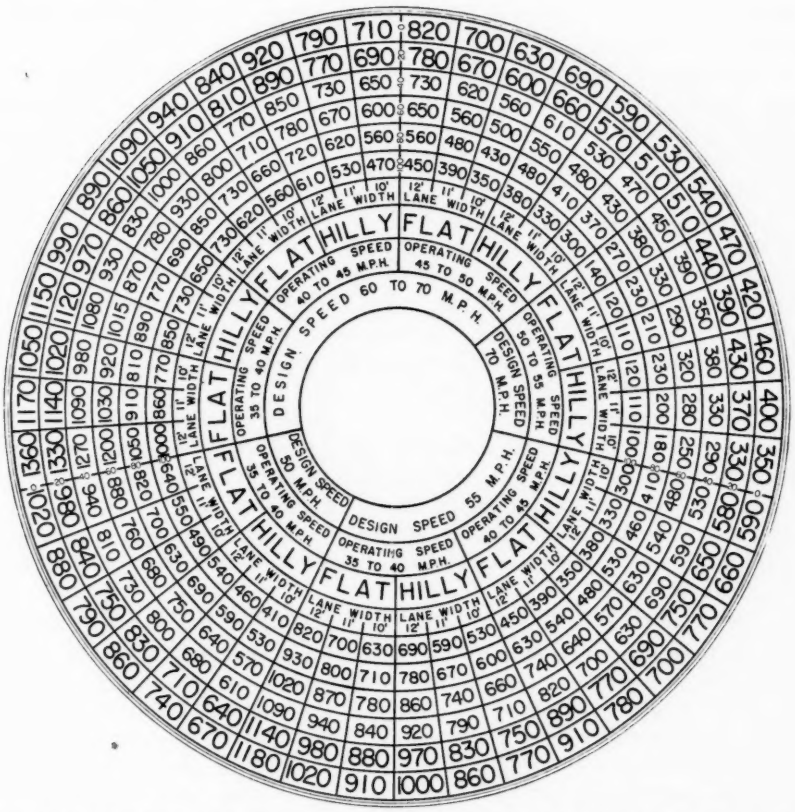

FIG. 1.—PRACTICAL WORKING CAPACITIES FOR 2-LANE RURAL ROADS IN TERMS OF TOTAL VEHICLES PER HOUR IN TWO DIRECTIONS

In accordance with the definition established by the Highway Capacity Committee, the capacity figures in the charts are practical working capacities —the maximum number of vehicles that can pass a given point during 1 hr without producing a traffic density so great as to cause unreasonable delay, hazard, or restriction to the driver's freedom to maneuver under the prevailing roadway and traffic conditions.

Practical Working Capacities for Two-Lane Rural Highways.—The first chart (Fig. 1), covering capacities for two-lane rural roads, sets up practical

capacities under 252 sets of conditions. These conditions include design speed, operating speed, terrain, lane width, and sight distance. Additional simple calculations that further refine the answers can be made for variations in the percentage of commercial vehicles. For the purposes of this chart, a commercial vehicle is considered to be any vehicle having dual tires. The values given in Fig. 1 include an assumed 10% of commercial vehicles. For each 1% that the actual number of commercial vehicles varies from the assumed figure, it is necessary to add or subtract 1% from the capacity figures in flat terrain or 2% from the capacity figures in rolling terrain. The outer six concentric circles of the chart indicate percentages of the roadway having less than 1,500 ft passing sight distance.

To illustrate the use of this chart in a state-wide highway planning study, assume that the problem is to determine whether a specific section of a two-lane highway is adequate for existing traffic volumes. The volume in peak hours is 580 vehicles per hr for both lanes, with 10% of the vehicles being commercial. It is desired to maintain an operating speed of 45 to 50 miles per hr, since the highway under consideration is a main state highway. The following conditions prevail: 60 to 70 miles per hr design speed; flat terrain; 11-ft lanes; and 60% of the road having less than 1,500 ft passing sight distance.

Referring to the chart, it is found that the practical working capacity of the section, under the prevailing conditions, is 560 vehicles per hr, or slightly under the existing volume. This indicates that the highway is adequate from a capacity standpoint for existing traffic.

Another example might be a section of two-lane rural highway that is deficient structurally and also operating beyond practical working capacities. The problem then is to determine the type of facility required to carry the maximum traffic volumes during the life of the facility.

Assume the following conditions: 60 to 70 miles per hr design speed; 40 to 45 miles per hr operating speed; hilly terrain; and 850 vehicles per hr required practical working capacity.

Referring to the chart, under the stated conditions this volume could be carried on a two-lane highway with 12-ft lanes and not more than 40% of the length of the roadway having less than 1,500 ft passing sight distance.

It is significant to note that, depending on the lane width and percentage of 1,500 ft passing sight distance available, the capacity of a two-lane rural road in flat country with an operating speed of 45 to 50 miles per hr can very from 350 to 820 vehicles per hr, a variation of more than 200%. Similar wide variations in capacity are found for other sets of conditions. The significance of the true economy of proper design has never been illustrated better.

Some rural roads are known to carry more vehicles per hour than are shown on this chart, but they do so only at the expense of reduced safe operating speeds.

Practical Working Capacities for Two-Way Streets.—City street capacities are affected by a wider variety of factors than are rural roads, and the second chart (Fig. 2.), covering capacities for two-way streets, includes more basic factors. The chart is first divided into the three accepted districts of a city—downtown, intermediate, and outlying. The factors of parking, percentage of

commercial vehicles, existence or prohibition of left turns, and curb to curb widths of streets are also taken into consideration. The chart gives directly the capacity under 144 sets of conditions. Interpolations may be made quickly for odd-width streets.

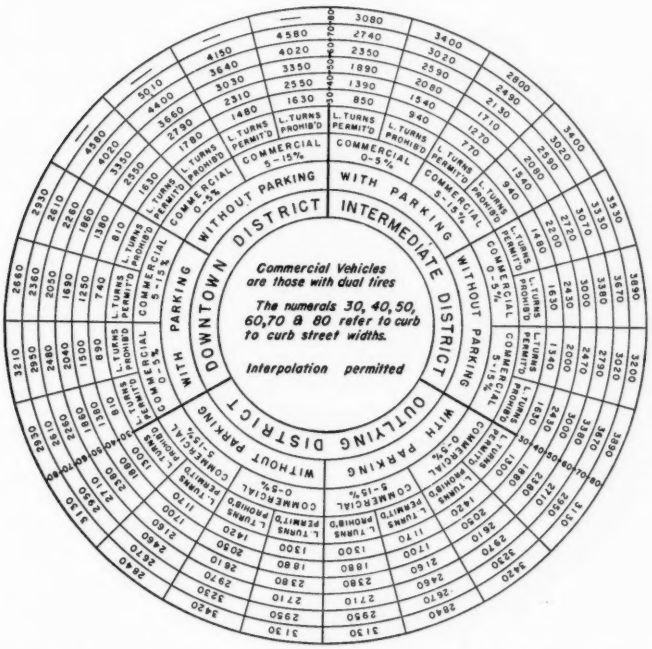

FIG. 2.—PRACTICAL WORKING CAPACITIES FOR 2-WAY STREETS IN TERMS OF TOTAL VEHICLES PER HOUR

Additional computations for special conditions are as follows:

(1) If commercial vehicles exceed 15% of the total traffic, subtract 1% from the capacity value for each 1% of commercial vehicles over 15%;

(2) If the street being studied is a bus route, multiply final value by 0.88;

(3) If the street is a streetcar route, regardless of district, use values of downtown—with parking;

(4) If fixed time signal is used, multiply the capacity by the ratio of green interval to total cycle; and

(5) If streetcar turns, deduct the time from the seconds of green.

This chart is used in the same manner as the chart for rural capacities, by checking through the appropriate conditions to arrive at the capacity figure and by making such adjustments for additional factors as may be required.

The basic data of the highway capacity committee, as condensed in this chart, illustrate dramatically the amazing increases in practical capacity that can be secured by comparatively inexpensive and simple methods, instead of the alternative of expensive widening or other major construction.

For example, the practical capacity of a 40-ft street in the downtown district, carrying 10% commercial traffic when both parking and left turns are permitted, is 1,250 vehicles per hr. If parking were eliminated during the rush hours and left turns prohibited, the practical capacity could be doubled to 2,550 vehicles per hr.

It is recognized that public support for such measures is often a problem. However, such facts as these enable the public and the public officials to decide intelligently whether or not the added capacity and its resulting freedom of movement and lessened congestion are worthwhile.

In the application of these data in appraising the capacity of existing streets, engineers are shown specifically the results that can be obtained by taking these other steps. Without this evidence, in some cases it might be wrongfully assumed that expensive construction is the only solution. These data will prove valuable also in reconciling the submission of construction projects in the light of other possible treatments.

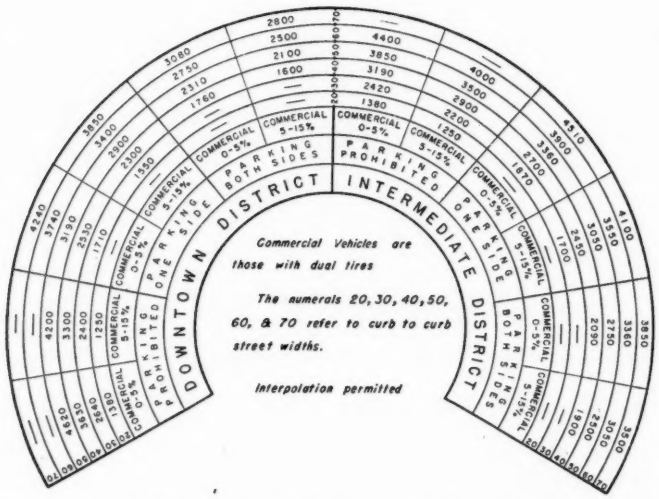

FIG. 3.—PRACTICAL WORKING CAPACITIES FOR 1-WAY STREETS IN TERMS OF TOTAL VEHICLES PER HOUR

Although the major increases in capacity that are possible through these steps are important and substantial, obviously, it must be recognized that such steps will not solve all problems and, under some conditions, major construction of freeways or other high-volume facilities is the only answer. However, proper application of these data does insure that all practical steps will be considered and that the resulting program will be both conservative and necessary. It should be noted that there is a very narrow margin between the practical working capacity as shown on Fig. 2 and the existance of undesirable or almost unbearable congestion.

Practical Capacities for One-Way Streets.—The third chart (Fig. 3) covers practical capacities for one-way streets and is similar to and includes the

same factors as the chart for two-way streets. In addition to its utility in determining the practical capacities of either existing or proposed one-way streets, the tabulation of basic material again quickly illustrates the efficiency of one-way streets when they can be established. For example, a 40-ft street in a downtown district, having a capacity of 2,550 vehicles per hr as a two-way street under the same basic conditions, could carry 3,630 vehicles per hr (or an increase of 42%) when operated as a one-way street.

In the application of these capacity data to long-range highway planning studies, similar determinations have been made for multi-laned divided rural highways and freeways, and for freeways in cities. Again, application of capacity determinants has helped to establish uniform standards for such facilities and results in a method for checking the need and the adequacy of proposed improvements.

ACKNOWLEDGMENT

The Bureau of Public Roads, the Highway Research Board Committee on Highway Capacity, and numerous state, county, and city engineers gathered the basic field data on capacity through countless observations over a long period of time. The Committee on Highway Capacity and, particularly, its chairman, Mr. Normann, and his assistants in the Bureau of Public Roads have worked many years in preparing the committee's report.

Glenn Logue and Harold Eckhardt, engineers of the Ohio Department of Highways, were principally responsible for devising the circular capacity charts used in this paper.

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